Stellar properties and chemical features of the Gaia Catalogue of Nearby Stars observed by GALAH DR4

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ABSTRACT

The *Gaia* Catalogue of Nearby Stars (GCNS) comprises approximately 330000 stars within 100 pc of the Sun, as observed by *Gaia* DR3. Meanwhile, the GALAH DR4 survey has spectroscopically characterised nearly one million stars, delivering high-value data including detailed chemical abundances (up to 30 elements), orbital properties, and cross-matches with other major catalogues (*Gaia* DR3, 2MASS, WISE). We present a joint analysis of the ~ 6000 stars common to both catalogues, securely matched using *Gaia* DR3 identifiers via TOPCAT, offering initial insights into the stellar and chemical properties of the solar neighbourhood. Our preliminary results indicate that the majority of these stars are FGK main-sequence objects, with some A-type interlopers (with effective temperatures ranging between 3000 and 8000 K), with median ages of 1.5 Gyr (ranging from 0.10 to 14.79 Gyr), and metal-poorer when compared to the Sun: $[Fe/H] = -0.19$ dex. Building on this foundation, future work will deeper exploit the full spectroscopic information and orbital parameters from value-added catalogues to refine Galactic component classifications (thin-thick disc versus halo membership), perform detailed chemical profiling, and deliver a comprehensive chemo-dynamical characterisation of the solar neighbourhood. This will provide new insights into the formation and evolution of nearby stellar populations.

1. INTRODUCTION

The detailed characterisation of stars in the solar vicinity provides a uniquely high-resolution window onto the Milky Way's formation and evolution. Variations in elemental abundances and orbital motions of these nearby stars act as chemical and dynamical fingerprints, allowing us to trace back their potential origins, identify co-eval groups, and reconstruct how enrichment and mixing processes have shaped the environment that directly influences the Solar System environment today. In this context, the European Space Agency's *Gaia* mission has provided an unprecedented astrometric view of the solar neighbourhood, with the *Gaia* Catalogue of Nearby Stars (GCNS) comprising approximately 330 K stars within 100 pc of the Sun, derived from *Gaia* Data Release 3 (Gaia Collaboration et al., 2016, 2021). Complementarily, large-scale spectroscopic surveys deliver detailed stellar parameters and chemical abundances that are fundamental for studying the chemo-dynamical properties of Galactic components. Among them, the GALAH survey Data Release 4 (Buder et al., 2025) has observed nearly one million stars, providing up to 30 elemental abundances, kinematic information, and robust cross-matches with major catalogues such as the *Gaia* DR3.

In this work, we explore a joint analysis of ∼6000 stars securely matched between the GCNS and GALAH DR4. By combining astrometric and spectroscopic information, our goal is to obtain a first characterisation of the stellar content within 100 pc, with emphasis on their chemical distribution and age properties, which will be discussed in the next section.

2. DATA AND METHODOLOGY

Below is the stepwise data processing and analysis path followed to produce the figures and statistics.

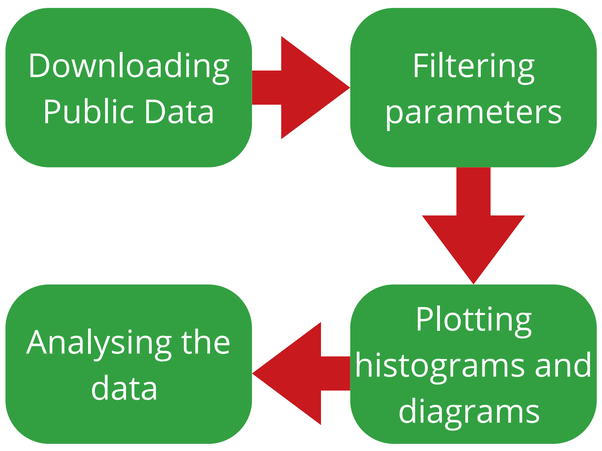

Figure 1: Schematic overview of our data processing and analysis workflow.

The key parameters analyzed include:

- Metallicity $[Fe/H]$: indicator of metal content relative to the Sun.
- Magnesium-to-iron ratio $[Mg/Fe]$: diagnostic to distinguish thin and thick Galactic disk populations.
- Effective temperature ($T_{\rm eff}$): measured in Kelvin (K).
- Surface gravity ($\log g$): logarithm of the stellar surface gravity.
- Stellar age: analyzed through age distribution histograms.
- Value Added Catalogues (VACs): additional parameters from GALAH DR4, such as other elemental abundances and dynamical parameters.

3. ANALYSIS AND RESULTS

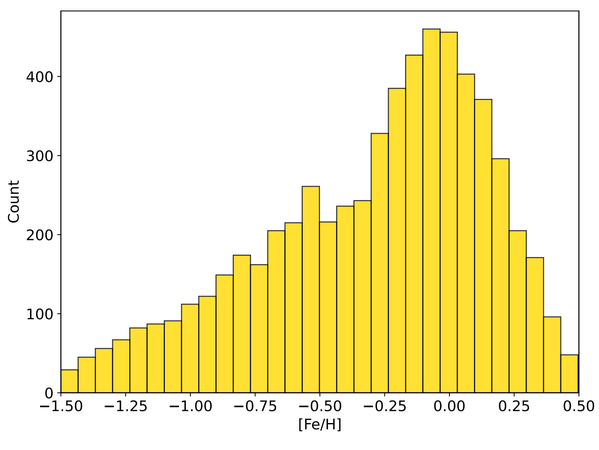

Figure 2: Histogram of $[Fe/H]$ within the defined filtered interval $[-1.5, 0.5]$ of our stellar sample. Median $[Fe/H] \approx -0.19$ dex.

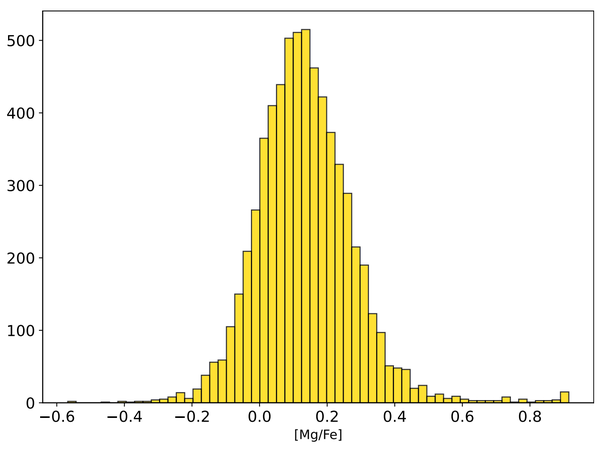

Figure 3: Histogram of $[Mg/Fe]$ for our stellar sample. Median $[Mg/Fe] \approx 0.12$ dex.

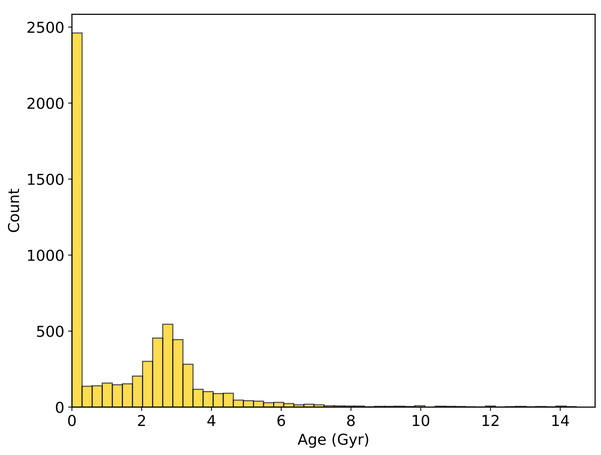

Figure 4: Age distribution of the stellar sample. The histogram shows a dominant peak near 1.5 Gyr (the median age) and an additional excess is visible between 0.1-2 Gyr. This younger age feature may arise from an isochrone degeneracy artifact or from genuine contamination by a younger sub-population; we do not attempt to separate the two possibilities here.

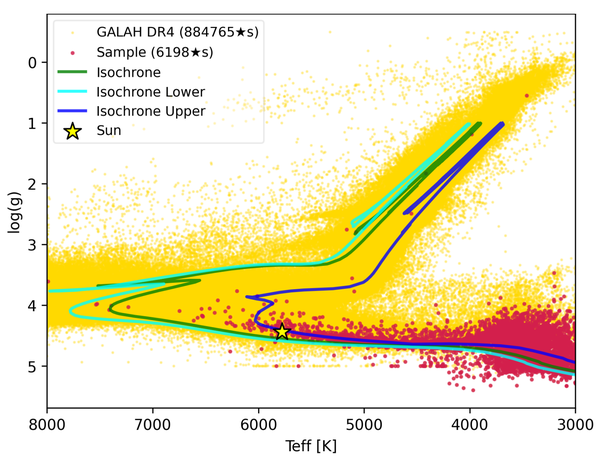

Figure 5: Kiel diagram showing $T_{\rm eff}$ versus $\log g$ for our joint sample. Overplotted are stellar isochrones ((Bressan et al., 2012)) centred at 1.5 Gyr with an uncertainty range of $\pm 1\sigma$, illustrating the typical age distribution of the sample. The stars in yellow are from GALAH DR4, while the reds are the matched sample.

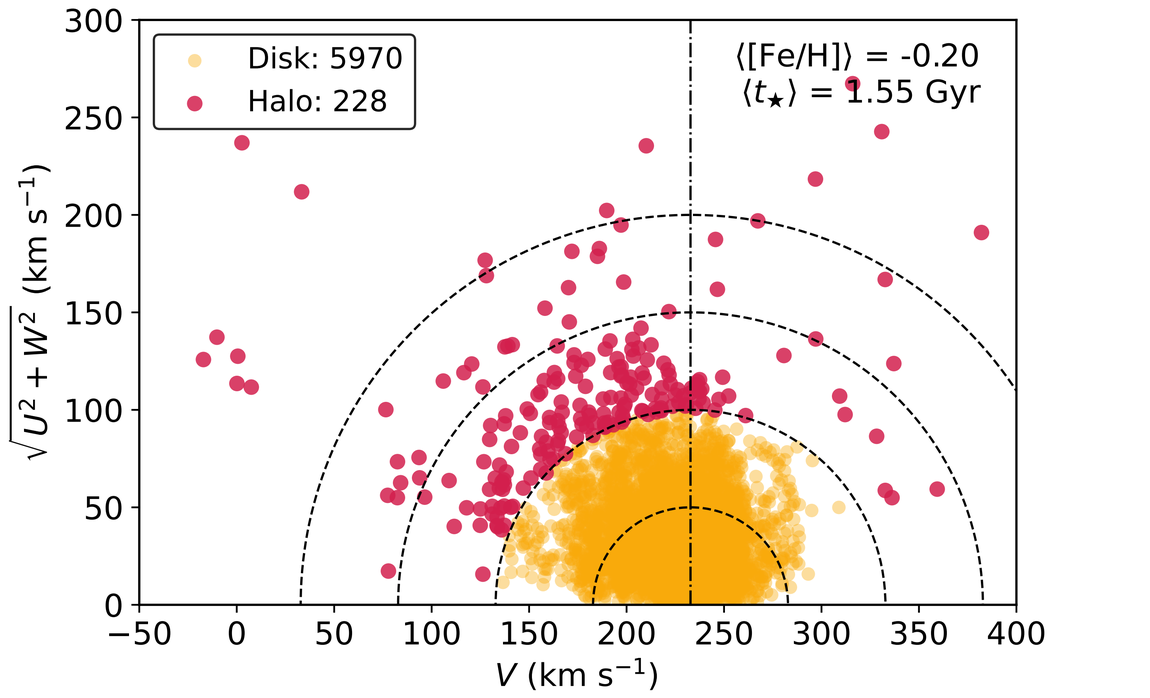

Figure 6: Toomre diagram for the Galactic velocity components (U, V, W) for the stellar kinematic populations. Concentric circles centered at 232.8 km/s represent velocity thresholds of 50, 100, 150, and 200 km/s. Velocities were corrected by adopting solar motion values $(U_\odot, V_\odot, W_\odot) = (8.6 \pm 0.9,\ 13.9 \pm 1.0,\ 7.1 \pm 1.0)$ km/s from McMillan, 2017. Stars above the 100 km/s threshold are more likely to belong to the halo, while the majority of stars are likely part of the disk.

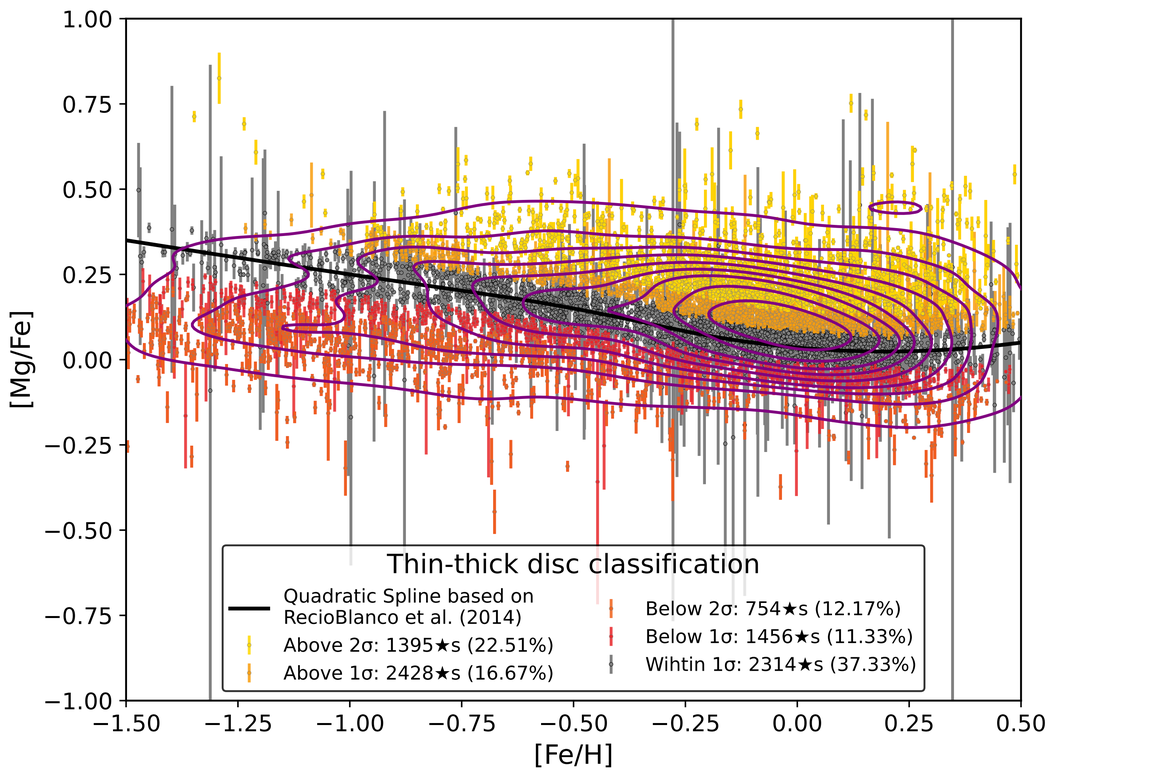

Figure 7: Correlation between $[Mg/Fe]$ and $[Fe/H]$ for our stellar sample. Stars above the reference quadratic spline-adopted from Recio-Blanco et al., 2014 are likely as thick disk, while those below belong to the thin disk. Grey points indicate stars within 1σ of the spline threshold. Thin disk stars are shown in shades of red, thick disk stars in shades of yellow, with varying opacity representing classification confidence within 1 or 2σ.

4. SUMMARY AND CONCLUSION

The preliminary joint analysis of the approximately 6000 stars matched between GCNS and GALAH DR4 reveals a population predominantly composed of FGK main-sequence stars, with a median age around 1.5 Gyr and a modest metal deficiency relative to the Sun, quantified as the median $[Fe/H] \approx -0.19$ dex in the solar neighbourhood stars. The Kiel diagram supports a consistency between the spectroscopic parameters and theoretical isochrones, confirming the reliability of the stellar parameter determinations. The Toomre diagram indicates a dominant disk population, with a small fraction of halo stars, as expected for the solar neighbourhood.The $[Mg/Fe]$–$[Fe/H]$ diagram shows that, among the thick disk stars in our sample, the metal-rich α-enhanced component is the most prevalent. This apparent metal-rich portion dominance is likely a consequence of the combined selection function of the GCNS and GALAH DR4.

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